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Title:

METHOD OF FORMING AN ISOLATION FILM IN A SEMICONDUCTOR DEVICE

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of forming an isolation film in a semiconductor device, and more particularly, to a method of forming an isolation film in a semiconductor device capable of preventing concentration of an electric field on the top corners of the trench in the isolation film of a STI (shallow trench isolation) structure.

Background of the Related Art

In all of the semiconductor devices, the isolation films for electrically isolating various devices formed in the semiconductor substrate are formed. Conventionally, the isolation film is formed by means of LOCOS (local oxidation) process. I n this case, however, a bird's beak occurs the corners of the isolation film. Due to this, there are problems that the electrical characteristics and degree of integration of the device are degraded.

As the degree of integration in the semiconductor device becomes higher, the isolation film is formed to have a STI (shallow trench isolation) structure that can minimize generation of the bird's beak at the isolation film while preventing generation of it.

A conventional method of forming the isolation film in the semiconductor device will be described by reference to FIG. 1A ~ FIG. 1D.

Referring to FIG. 1A, a pad oxide film **102** and a pad nitride film **103** are sequentially formed on a semiconductor substrate **101**. A photoresist is then covered on the pad nitride film **103**. N ext, exposure and development processes are implemented to form a photoresist pattern **104** in which an isolation region where the isolation film will be formed is defined. T hereby, the pad nitride film **103** in the region where the isolation film is to be formed is exposed.

By reference to FIG. 1B, the pad nitride film **103** in the isolation region is removed through an etch process. T he pad oxide film **102** exposed below is then sequentially removed. T hereby, the semiconductor substrate **101** in the isolation region is exposed.

Referring to FIG. 1C, the semiconductor substrate **101** in the isolation region is etched by a given depth to form a trench **105**. N ext, the photoresist pattern (**104** in FIG. 1B) is removed.

By reference to FIG. 1D, an insulating material layer (not shown) is formed so that the trench **105** is buried. N ext, the insulating material layer on the pad nitride film (**103** in FIG. 1C) is removed by means of a chemical mechanical polishing process. A lso, the pad nitride film and the pad oxide film (**102** in FIG. 1C) are sequentially removed by means of an etch process. T hereby, the insulating material layer remains only in the trench to form an isolation film **106** consisting of the insulating material layer.

The isolation film formation method described above will be examined. I n case that the isolation film is formed to have the STI structure, the bird's beak does not occur. T herefore, it is possible to prevent degradation in the electrical characteristics and the degree of integration due to the bird's beak.

However, the most vulnerability in the isolation film of the STI structure is that the electric field is concentrated on a portion where the top corners of the trench (**105a** in FIG. 1C) are sharp-pointed. I f the top corners of the trench are thus pointed, a gate oxide film is thinly formed at this portion, which increases the leakage current at this portion. T he electric field is concentrated on that portion, which may change the threshold voltage of the transistor and cause defect in the device. T herefore, there is a problem that reliability of the device is degraded.

A method of preventing this is one by which the photoresist pattern is used as an etch mask without using the pad nitride film as the etch mask when the substrate is etched to form the trench. T his method will be described in detail.

In FIG. 1C, in the state that the photoresist pattern remains in tact on the pad nitride film **103** without removing the photoresist pattern, as in FIG. 1B, if a polymerization reaction is generated using an etchant upon etch of the substrate for

forming the trench, polymer is accumulated on the substrate at the corners of the isolation region while polymer is generated. A s a silicon component and an etch selectivity ratio are different in the accumulated polymer, the accumulated polymer serves as an anti-etch film when the substrate is etched. D ue to this, the corners of the isolation region on which polymer is accumulated is rarely etched compared to the center of the isolation film. T herefore, the top corners of the trench are made rounded.

However, this method could not exactly control the amount of generation of polymer. I t is thus difficult to uniformly form the top corners of the trench in a rounded shape. F urthermore, in case that the photoresist pattern is used as the etch mask, it becomes difficult to etch the semiconductor substrate due to polymer occurring in the photoresist as the pattern size is integrated. A ccordingly, it is required that the semiconductor substrate be etched with the photoresist pattern removed. H owever, when the pad nitride film is used as the etch mask with the photoresist pattern removed, carbon source for generating polymer is short. Therefore, it is further difficult to make rounded the top corners of the trench using polymer.

SUMMARY OF THE INVENTION

Accordingly, the present invention is contrived to substantially obviate one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a method of forming an isolation film in a semiconductor device, in the process of forming a stack structure of a pad oxide film and a pad nitride film that expose a semiconductor substrate in an isolation region, forming protrusions of a tail profile at the bottom sidewalls of the pad nitride film and the pad oxide film adjacent to the surface of the substrate and making rounded the top corners of a trench using the protrusions as an anti-etch film when the semiconductor substrate is etched, whereby concentration of an electric field on the top corners of the trench is prevented and generation of the leakage current is prohibited, thus improving reliability of the process and electrical characteristics of the device and simultaneously solving a difficult of the process for

polymer since the top corners of the trench is made rounded even with the photoresist pattern removed.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. T he objectives and other advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a method of forming an isolation film in a semiconductor device according to a preferred embodiment of the present invention is characterized in that it comprises the steps of sequentially forming a pad oxide film and a pad nitride film on a semiconductor substrate, removing the pad nitride film and the pad oxide film on an isolation region so that protrusions of a tail profile are formed at the top corners of the isolation region, etching the semiconductor substrate of the isolation region, while using the protrusions as an anti-etch film, to form a trench the top corners of which are made rounded, and burying the trench with an insulating material and then removing the pad nitride film and the pad oxide film on the semiconductor substrate to form an isolation film.

In the above, the protrusions may be formed by implementing an over-etch process using a CHF_3 gas during 1 ~ 10% of time taken to remove the pad nitride film after the pad nitride film in the isolation region is removed. A lternatively, the protrusions may be formed by implementing an etch process with a high selectivity ratio to oxide in the etch process for removing the pad nitride film and the pad oxide film. M eanwhile, the etch process is implemented using a CF_4 gas and a CHF_3 gas as an etch gas and wherein the CHF_3 gas is more supplied than the CF_4 gas so that the selectivity ratio to oxide is increased. A t this time, it is possible to control the supply ratio of the CHF_3 gas and the CF_4 gas at the ratio of 2:1 ~ 10:1. T his etch process is implementing by setting a time point when an oxide component of the pad oxide film is detected as an end of point (EOP).

Furthermore, a photoresist pattern is formed on the pad nitride film in order to define the isolation region. A t this time, the photoresist pattern is removed before the trench is formed after the pad nitride film and the pad oxide film on the isolation region are removed, so that polymer occurring from the photoresist is prevented to affect an etch process for forming the trench.

The etch process for forming the trench may be implemented in-situ with no time delay at the etch chamber by which the pad nitride film and the pad oxide film are removed, in order to prevent a native oxide film from being formed on the semiconductor substrate of the isolation region.

The etch process for forming the trench may include the steps of performing a first etch process for the semiconductor substrate only with a process condition having a high selectivity ratio to the protrusions to form the trench the top corners of which are not made rounded, and performing a second etch process, using a post etch treatment (PET) with a process condition having a low selectivity ratio to the protrusions, to form etch tilt faces at the top corners of the trench while removing the protrusions, thereby forming the trench that is made rounded. A t this time, the etch selectivity ratio to the protrusions and the semiconductor substrate is controlled by adjusting the flux of an HBr gas among etch gases. I n the first etch process, the semiconductor substrate only is etched by increasing the flux of the HBr gas. I n the second etch process, the top corners of the trench along with the protrusions are etched by relatively reducing the flux of the HBr gas.

In another aspect of the present invention, it is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

FIG. 1A ~ FIG. 1D are cross-sectional views of the semiconductor devices for explaining a conventional method of forming an isolation film in the semiconductor device;

FIG. 2A ~ FIG. 2E are cross-sectional views of the semiconductor devices for explaining a method of forming an isolation film in the semiconductor device a preferred embodiment of the present invention; and

FIG. 3A and FIG. 3B are cross-sectional views of the semiconductor devices for explaining an embodiment of the etch process for forming the trench in FIG. 2C.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, in which like reference numerals are used to identify the same or similar parts.

FIG. 2A ~ FIG. 2E are cross-sectional views of the semiconductor devices for explaining a method of forming an isolation film in the semiconductor device a preferred embodiment of the present invention.

Referring to FIG. 2A, a pad oxide film **202** and a pad nitride film **203** are sequentially formed on a semiconductor substrate **201**. A photoresist is then covered on the pad nitride film **203**. N ext, exposure and development processes are implemented to form photoresist patterns **204** in which an isolation region where an isolation film will be formed is defined. T he pad nitride film **203** in the region where the isolation film is to be formed is thus exposed. A t this time, it is preferred that the pad nitride film **203** is formed in thickness of below 1500□.

By reference to FIG. 2B, the pad nitride film **203** in the isolation region is removed through an etch process. T he pad oxide film **202** exposed below the pad nitride film **203** is then removed, thereby exposing the semiconductor substrate **201** in the isolation region. A t this time, in the process of removing the pad nitride film **203** and the pad oxide film **202** in the isolation region, protrusions **230** of a tail profile are formed at the bottom sidewalls of the pad nitride film **203** and the pad oxide film **202** coming into contact with the surface of the semiconductor substrate **201**. A t this time, the protrusions **230** serves as an anti-etch film that prevents the

corners of the isolation region from being etched in a subsequent process of etching the semiconductor substrate **201** to form a trench.

Even though there are many methods for forming these protrusions **230**, two embodiments as examples will be described.

As a first method, in the etch process of removing the pad nitride film **203** in the isolation region, the protrusions **230** may be formed by a method of controlling the process condition on the etch gas and over-etch. More concretely, during 1 ~ 10% of time taken to remove the pad nitride film **203** after the pad nitride film **203** in the isolation region is etched, over-etch is implemented using a CHF_3 gas. At this time, if the over-etch process is implemented using the CHF_3 gas, polymer occurs. As the over-etch process is performed in a short period of time, however, the protrusions **230** is formed while polymer is accumulated on the bottom sidewalls of the pad nitride film **203** and the pad oxide film **202**.

As a second method, in the etch process of removing the pad nitride film **203** and the pad oxide film **202** in the isolation region, the protrusions **230** may be formed by controlling the etch selectivity ratio of the pad nitride film **203** and the pad oxide film **202**. More concretely, the pad nitride film **203** is usually removed by means of an etch process using a CF_4 gas and a CHF_3 gas. Generally, the CF_4 gas is more supplied than the CHF_3 gas. If the CHF_3 gas is more supplied, however, the selectivity ratio to oxide becomes low. Due to this, the protrusions **230** of the tail profile consisting of nitride/oxide are formed while the etch tilt faces are formed at the lower sidewalls of the pad oxide film **202**. At this time, the CHF_3 gas and the CF_4 gas may be supplied at the ratio of 2:1 ~ 10:1. Meanwhile, in this case, when the pad nitride film **203** and the pad oxide film **202** are etched, a time point when a silicon component of the semiconductor substrate **201** is detected is not set as an end of point (EOP). Instead, a time point when an oxide component of the pad oxide film **202** is detected is set as EOP.

As in the above, if the pad nitride film **203** and the pad oxide film **202** in the isolation region are removed by means of the etch gas and the over etch process or by controlling the etch selectivity ratio of the pad nitride film **203** and the pad oxide film

202, the protrusions **230** of the tail profile is formed at the bottom sidewalls of the pad nitride film **203** and the pad oxide film **202**.

Referring to FIG. 2C, the photoresist pattern (**204** in FIG. 2B) is removed. The semiconductor substrate **201** of the isolation region is then etched by a given depth to form a trench **205**. At this time, as the protrusions (**230** in FIG. 2B) formed at the top corners of the isolation region hinders the corners of the isolation region from being etched, etch tilt faces are formed at the top corners **205a** of the trench **205**. Due to this, the top corners **205a** of the trench **205** is made rounded.

In the above, before the trench **205** is formed after the pad nitride film and the pad oxide film of the isolation region is removed, an etch process is usually implemented in order to remove a native oxide film formed on the surface of the exposed semiconductor substrate. However, if the etch process is performed in order to remove the native oxide film, the protrusions **230** may be damaged. Therefore, in order to prevent formation of the native oxide film from the beginning, the trench is formed in the isolation region in-situ with no time delay at the etch chamber by which the pad nitride film and the pad oxide film are removed. As thus, if the semiconductor substrate **201** is in-situ etched to form the trench, it is possible to omit the etch process for removing the native oxide film. Accordingly, there is an advantage that the process step is reduced.

Meanwhile, in the etch process for forming the trench **205**, the etch process by which the top corners of the trench **205** is made rounded using the protrusions may be implemented in various methods. This will be below described in more detail.

As a first method, if the trench **205** is formed by means of the etch process of a common semiconductor substrate **201**, the protrusions **230** are more slowly etched when the semiconductor substrate **201** is etched while the etch tilt faces are naturally formed at the corners of the isolation region, whereby the trench **205** that is rounded is formed.

As a second method, the trench **205** the top corners of which are made rounded by twice etch processes may be formed by controlling the etch selectivity ratio to the protrusions **230** consisting of nitride and oxide and the semiconductor substrate **201**. This will be described in more detail by reference to FIG. 3A and

FIG. 3B. FIG. 3A and FIG. 3B are cross-sectional views of the semiconductor devices for explaining an embodiment of the etch process for forming the trench in FIG. 2C.

Referring to FIG. 3A, in a state that the protrusions **230** consisting of nitride and oxide are formed at the bottom sidewalls of the pad nitride film **203** and the pad oxide film **202**, only the semiconductor substrate **201** is etched using a process condition having a high selectivity ratio to the protrusions **230**, thus forming the trench **205** the top corners **205a** of which are not rounded.

By reference to FIG. 3B, the etch tilt faces are formed at the top corners **205a** of the trench **205** to form the trench **205** that is made rounded, while removing the protrusions (**230** in FIG. 3A), by implementing a PET (post etch treatment) process with a process condition having a low selectivity ratio to the protrusions **230**. At this time, the etch selectivity ratio to the protrusions (**230** in FIG. 3A) and the semiconductor substrate **201** could be controlled by adjusting the flux of the HBr gas only among the etch gases. In other words, in a first etch process, the semiconductor substrate **201** only is etched by increasing the flux of the HBr gas. In a second etch process, the top corners **205a** of the trench **205** along with the protrusions (**230** in FIG. 3A) are etched by relatively reducing the flux of the HBr gas.

At this time, one of the most important characteristics of the present invention why the trench is formed by the above method, is as follows. As the trench is formed with the photoresist pattern removed, the trench is not affected by polymer occurring from the photoresist. Therefore, the etch process could be more accurately controlled and reliability of the process can be thus improved.

Referring to FIG. 2D, an insulating material layer **206** is formed on the entire structure so that the trench **205** is buried.

By reference to FIG. 2E, the insulating material layer (**206** in FIG. 2D) on the pad nitride film (**203** in FIG. 2D) is removed by means of a chemical mechanical polishing process. The pad nitride film and the pad oxide film (**202** in FIG. 2D) are then sequentially removed by means of an etch process. Thereby, the insulating material layer remains only at the trench (**205** in FIG. 2D) the top corners of which

are made rounded, thus forming the isolation film **207** consisting of the insulating material layer.

As described above, when the isolation film of the STI structure is formed using the above method, the present invention has the following advantageous effects.

First, as the protrusions are formed by adjusting time taken to implement the over-etch process or the mixed ratio of the etch gas when they are formed, the profile of the protrusions could be exactly controlled. A ccordingly, as the top corners of the trench could be uniformly made rounded, reliability of the process is improved.

Second, the trench is formed by in-situ etching the semiconductor substrate with no time delay in the etch chamber by which the pad nitride film and the pad oxide film are removed. I t is thus possible to prevent formation of the native oxide film. A ccordingly, it is possible to omit a cleaning process for removing the native oxide film and thus to reduce the process step and time.

Third, as the top corners of the trench are formed to be round, concentration of an electric field is prevented. A ccordingly, it is possible to prevent variation in the threshold voltage of the semiconductor device such as the transistor.

Fourth, as the top corners of the trench are formed to be round, concentration of an electric field is prevented. A ccordingly, it is possible to generation of dislocation of silicon.

Fifth, as the top corners of the trench are formed to be round, it is possible to prevent the gate oxide film from being thinly formed in a subsequent process. Accordingly, it is possible to prohibit an increase in the leakage current.

Sixth, as the top corner of the trench could be formed to be round even with the photoresist pattern removed, existing problems in the process that made difficult to remove the photoresist pattern and to make rounded the top corners of the trench could be solved.

The forgoing embodiments are merely exemplary and are not to be construed as limiting the present invention. T he present teachings can be readily applied to other types of apparatuses. T he description of the present invention is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art.